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Renormalization of KOREL-Decomposed SB2 Spectra

Holger Lehmann[1] **and Andrew Tkachenko**[2]

[1]Thüringer Landessternwarte Tautenburg, D-07778 Tautenburg, Germany
email: lehm@tls-tautenburg.de

[2]Instituut voor Sterrenkunde, Celestijnenlaan 200B, B-3000 Leuven, Belgium
email: andrew@ster.kuleuven.be

Abstract. We introduce a new computer program that is able to determine the flux ratio between the components of SB2 stars from time series of composite spectra. The spectra of the components are decomposed using the KOREL program and compared to synthetic spectra computed on a grid of fundamental stellar parameters. In the result, we obtain the optimized stellar parameters together with the flux ratio. The program is tested and applied to the oscillating eclipsing binary KIC 10661783 observed by the Kepler satellite mission.

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1. The method and its test

Like other programs for spectral disentangling, the Fourier-transform-based KOREL program (Hadrava 1995) computes the decomposed spectra of multiple stellar systems normalized to the common continuum of all components. One needs information about the continuum flux ratio between the components to be able to renormalize the decomposed spectra accordingly. There exists already one method called GENFITT (Tamajo *et al.* 2011) that computes the flux ratio directly from the spectra itself using a genetic algorithm. We show in this investigation that it is possible to determine the wavelength dependent flux ratio between the two stars of a binary directly from a comparison between observed and synthetic spectra by solving a simple linear system.

We use a library of synthetic spectra computed on a grid in $T_{\rm eff}$, $\log g$, [M/H], and $v\sin i$ (Lehmann *et al.* 2011) and define a χ^2 that measures the combined accuracy from comparing the decomposed spectra separately with the synthetic ones. Assuming a linear trend of the flux ratio of star k with wavelength, $f_k = f_{k,0} + f_{k,1}\lambda$, and setting the partial derivatives of χ^2 with respect to the $f_{k,j}$ to zero, one gets a system of linear equations that can directly be solved. A detailed derivation will be given in a forthcoming paper.

The accuracy of the derived parameters will depend on the S/N of the composite spectra, the flux ratio and the $v\sin i$ of the components, and on the accuracy of the continuum normalization of the observed spectra. We tested the program on artificial spectra computed for two components of [M/H]=0.1 and $T_{\rm eff}$=7900/6500 K, $\log g$=3.6/4.3, and $v\sin i$=80/50 km s^{-1} for the primary/secondary, respectively. For the flux ratio of the secondary, we used 0.1 and 0.5. The local continuum of the observed spectra is not *a priori* known. Thus, we compared the results obtained for a fixed (true) continuum of the composite spectra and for a continuum that was corrected by adapting it to those of the synthetic spectra as it is the preferred method in practice. The calculations were done on the wavelength range from 3850 to 5670 Å, the different S/N (100 to 400) have been realized by adding scaled, Poisson-distributed noise to the artificial spectra.

The results show that our program works well for high-S/N spectra. It computes well-constrained flux ratios (error below 2%) in all test cases. The influence of the accuracy of

Table 1. Comparison of fundamental parameters of KIC 10661783. $T_{\rm eff\,2}$ and $\log g_2$ are given with reflection, the spectroscopic flux ratio f_2/f_1 without/with reflection.

		Kepler light curve	spectroscopic & combined			
P	(d)	1.2313622(2)	1.2313622 fixed	$\log g_{1/2}$		3.6(1)/4.3(5)
T	(K)	2455065.77701(5)	2455065.778(6)	$M_{1/2}$	($M_\odot$)	2.1(2)/0.18(2)
q		0.0626(8)	0.089(3)	$v_{1/2}\sin i$	(km s^{-1})	81(4)/48(4)
i	(°)	82.8(2)		$R_{1/2}$	($R_\odot$)	2.0(1)/0.88(5)
f_2/f_1		0.086(9)	0.074(4)/0.03(3)	a	($R_\odot$)	6.3(1)
$T_{\rm eff\,1/2}$	(K)	8000/6500 (assumed)	7890(25)/6760(720)			

the continuum normalization is remarkable. For the faint secondary (f=0.1), the accuracy in $T_{\rm eff}$ and $\log g$ drops down by a factor of two if we allow for adjusting the continuum as we have to do in practice. This effect will be the stronger, the more the spectra are blended, i.e. the bluer the spectral region and the later the spectral type. In our case, we need at least S/N of 200 to determine its $T_{\rm eff}$ within ±200 K and its [M/H] within ±0.15 dex and S/N of 400 for its $\log g$ within ±0.25 dex. When both components are of about the same brightness, $T_{\rm eff}$ can be determined by ±70 K for S/N⩾100, $\log g$ by ±0.1 for S/N⩾200, and [M/H] by ±0.1 for S/N⩾200.

2. First application to KIC 10661783

The test parameters had been chosen in a way to fit the suspected stellar properties of KIC 10661783, an eclipsing binary that shows more than 60 δ Sct-like oscillations in its light curve observed by the Kepler satellite (Southworth *et al.* 2011). We determine its fundamental stellar parameters from a time series of high-resolution spectra taken with the HERMES spectrograph at the Mercator Telescope on La Palma.

Our analysis results in a flux ratio of 0.074 between secondary and primary and about 8000 K for $T_{\rm eff}$ and 3.6 for $\log g$ of both components. The identical parameters are in agreement with the fact that the decomposed spectra of both components are almost identical if we up-scale the line depths of the secondary by a factor of about 14. Although the flux ratio agrees with that obtained from the light curve analysis, the parameters derived for the secondary are not compatible with the photometric results and in particular not with the derived mass ratio of 0.089. As a possible explanation, we assume that the light in the decomposed spectrum of the secondary contains a remarkable contribution of reflected light from the primary. This would also explain that during both eclipses the RVs of the secondary show the Rossiter effect and its line strengths are strongly weakened. We extended our program accordingly, using a very simple model including synchronized rotation and pure reflection. Table 1 compares our results with those of the light curve analysis. We end up with the very small flux ratio of 0.033 that prevents us from obtaining more accurate values. Independent of reflection, we derived the masses and radii of the components and their separation of only 3.2 R_1. The hypothesis of reflected light has to be checked using the Wilson-Devinney code with the Kepler light curve.

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